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# CO-OPERATION ON METEOROLOGICAL TACTICAL DECIS1ON AIDS WITHIN NATO

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## ABSTRACT

The Military Committee Meteorological Group (MCMG) is responsible for advising the North Atlantic Treaty Organisation (NATO) Military Committee (MC) on meteorological matters affecting NATO. It also acts as the co-ordinating agency of the MC for all meteorological policies, procedures and techniques within NATO. The MCMG is supported by two working groups: WG-OPC (Operations, Plans and Communications) and WG-BMSS (Battle-area Meteorological Systems and Support). The mission of the WG-BMSS is to support the MCMG in carrying out its functions of encouraging co-operative effort and interoperability in the area of meteorological research, development, and transition of new equipment, techniques and software to operational capability in the field of maritime operations, air operations and specifically land operations.

In particular the WG-BMSS has a programme of work on the development, exchange and interoperability of land, air and maritime Tactical Decision Aids (TDAs) having battle-area environmental and/or meteorological parameters as an input. This includes TDAs for a wide range of applications including acoustic propagation, atmospheric dispersion, electro-optical and electromagnetic systems, icing (airframes, runways and ships) predictions, trafficability and topographic/geographical analyses. This paper outlines the background to this work programme, which has the objective of producing a filly documented NATO library of meteorological TDAs, and discusses some of those TDAs that have been offered by individual nations together with verification and validation results where available.

## 1. BACKGROUND

The Military Committee Meteorological Group (MCMG) advises the North Atlantic Treaty Organisation (NATO) Military Committee (MC) on meteorological matters affecting NATO. It also acts as the co-ordinating agency of the MC for all meteorological policies, procedures and techniques within NATO. The history of the MCMG dates back to 1950 when it first met as the Standing Group Ad Hoc Meteorological Information Committee. Almost immediately it became the Standing Group Meteorological Committee (SGMC). In 1968 the group became known as the MCMG and since 1954 it has been supported by one or more working groups. Currently the

MCMG is supported by two working groups: WG-OPC (Operations, Plans and Communications) and WG-BMSS (Battle-area Meteorological Systems and Support).

The mission of the WG-OPC is to support the MCMG by identifying and correcting deficiencies in NATO's operational meteorological organisation, plans and communications. WG-OPC is responsible for maintaining the AWP (Allied Weather Publication) series of documents. These are AWP- 1 (B) the NATO Maritime Meteorological Procedures and Services Manual, AWP-2 the NATO Meteorological Support Manual, AWP-3(A) the NATO Meteorological Communications Manual and AWP-4 the NATO Meteorological Codes Manual. In particular AWP-2 describes the level of meteorological support required for NATO maritime, air and land operations. This includes providing basic meteorological data and forecasts, together with more specialised products for mission-specific and tactical planning. For the latter, basic weather forecasts are not sufficient and more detailed predictions prepared using Tactical Decision Aids (TDAs) are needed. These incorporate weather and environmental information, together with information on the mission and the equipment being used (e.g. platforms and sensors). Thus TDAs are tools that allow the meteorologist, or the operator, to predict the effect that meteorological and environmental conditions have on military systems and equipment, and the impact that this might have on a specific operation.

The mission of the WG-BMSS is to support the MCMG by encouraging co-operative effort and interoperability in the area of meteorological research and development. The working group follows the transition of equipment, techniques and software from the developmental stage to operational status within the military meteorological community. An important aspect of this task is in encouraging the development, exchange and interoperability of TDAs for land, air and maritime applications. This work started a number of years ago when the group existed as ISWG.3 (Independent Special Working Group No. 3 on Meteorology) within the NAAG (NATO Army Armaments Group). As ISWG.3 under the NAAG the focus of the group was on the development of TDAs specifically for supporting Army operations. This effort was in addition to the groups responsibility in artillery meteorology, maintaining a series of artillery meteorology STANAGS, and providing support to other NAAG Panels. With the transfer of the group in 1995, from the NAAG to the MCMG, there is now an increased emphasis towards the work on meteorological TDAs, and the scope of this work has been extended to cover TDAs for air and maritime applications.

Over the years a significant number of TDAs have been developed by different nations within NATO and there is a growing need to harmonise, or standardise, on the TDAs or the models being used. This is likely to be particularly important in the context of multi-national operations, where the provision of consistent tactical advice is essential. Furthermore, the various models used to support air, land and maritime operations should produce consistent results. The objective of the WG-BMS S work is to develop a fully documented NATO library of meteorological TDAs which can then be made available for use by all NATO nations. It is envisaged that this will comprise a library of ready-to-use (i.e. executable) TDAs suitable for use on a standard PC or low-end workstation. In addition to this, it is also hoped to provide a library of TDA/TDA sub-model source codes so that individual nations, if they prefer, can build their own TDA packages, but still maintain consistency. It is planned that this library of TDAs/TDA sub-models will be documented by a new AWP manual (AWP-5). Through this work on TDAs, the WG-BMSS is promoting interoperability and, by the collective nature of the work, assisting the different nations in improving their meteorological support capabilities; thus helping to offset the effects of budget cuts, to which no nation is immune. The first stage of this work is to develop a catalogue of TDAs as described below.

## *2.* CATALOGUE OF TDAs AND SUPPLEMENTARY INFORMATION

The group is currently in the process of developing an inventory of TDAs comprising several matrices; the first part is a summary matrix simply listing TDAs by name and application for each nation. Table 1 shows a subset of some of the summary information, which is as yet incomplete.

However, not all those TDAs that have been identified/notified are likely to be available for release within NATO. This may be due to national interests and/or commercial considerations, and this information also needs to be compiled. Therefore the second part of the inventory contains further information regarding the TDA application, owner (or developer), status (e.g. under development or in operational use) and its availability for release. Recently compiled information has resulted in a list identifying national priorities with respect to the importance and relevance of each TDA application. Whilst this list is not complete, inputs received so far suggest that the areas of IR (infrared), visible/near IR, electromagnetic (lW/p-wave) propagation, airframe icing, personnel factors (i.e. heat stress/wind chill), NBC/smoke and runway icing are of wider interest.

In addition to this catalogue of TDAs, various other supplementary matrices are being compiled by WG-OPC on the availability of weather data for running TDAs and on the weather support capabilities. The first of these identifies the various types of weather data (observational data, NWP products and gridded data, satellite data etc.) that are available at different echelons (military forecast centre, airfield, at sea, mobile met unit etc.). The second focuses on the support capabilities (e.g. processing equipment, communications, personnel) available at these echelons. Thus, these two supplementary matrices provide valuable information on identifying where, or how far down the echelon structure, the various TDAs could be used.

The next stage in this work is to review the various TDAs, by application, in order to make recommendations towards a NATO approved TDA or TDA models. Individual nations have accepted the task of reviewing TDAs, on behalf of the group, for different application areas, as shown in Table 2. In this way the workload is being shared amongst the nations.

The various TDAs, for each of the specific applications shown, have been provided (where available) to the designated nation to review in detail. These reviews should include an assessment of the physics contained in the models, and validation and verification of the results where such data is available. In some cases, where there are a number of nations with expertise in the subject it is expected that ad-hoc working groups may be established to assist the lead nation in the review process and in formulating recommendations. These recommendations would then be presented to the WG-BMS S to collectively discuss candidate TDAs before making any decisions on which TDAs, or TDA sub-models, should be adopted. In some cases the preferred approach may well be a hybrid of different TDA sub-models originating from different nations.

| **TDAs for** | **CA** | FR | **GE** | **UK** | **US** |
|---|---|---|---|---|---|
| IR<br>(8-12 pm) | ✓ | | NAVFLIR | EOTDA v2<br>IRVIS | TARGAC<br>EOTDA 3.1<br>EOMDA<br>*ACT/EOS* |
| IR<br>(3-5 µm) | | | NAVFLIR | | *EOMDA*<br>*ACT/EOS* |
| Visible/Near IR<br>(.7-.9 µm) | ANVIS | | BIVPROG | ILLUMW | NVG<br>TARGAC<br>NITELITE<br>*NOWS* |
| Visible<br>(.4-.7 pm) | ANVIS | | BIVPROG | ILLUMW | NVG<br>TARGAC<br>NITELITE<br>*NOWS* |
| EM (RF/µ-wave Propagation) | IREPS<br>*TEMDA* | RADAR | IR-RADAR<br>IREPs<br>EREPS | IREPs<br>EVDUCTW<br>*EEMS*<br>*(TERPEM)* | IREPS<br>RPOT |
| EM (HF Propagation) | ✓ | | MINIFTZ | *EEMS (JIVE)* | PROPHET<br>IREPS |
| Acoustic Propagation | ✓ | | SNDCAL | LARKW<br>APP | Acoustic<br>TDA |
| NBC/Smoke | ✓ | | HEARTS<br>AUTAG | BRACIS<br>*CHEBDA* | KWIK<br>VLSTRACK |
| Airframe Icing | Tephi<br>IFW<br>AIFC | | POTICE<br>STANDICE | NWP<br>products | ICING |
| Airfield Runway Icing | | | RIME | RSTW | |
| Ship Icing | | | | | Topside Icing<br>Model |
| Heat Stress/<br>Wind Chill | HUMID<br>WINDCHILL | | | HUMPARS | MERCURY |
| Trafficability | ✓ | | CACTUS | SOILM | DTSS |
| Parachute Operations | | High Altitude<br>Opening | | DZ WIND | |
| Weather Effects | | | FOGMIN<br>GUST<br>JETLIGHT | | IWEDA<br>TESS |

Table 1. Allied Tactical Decision Aids. Adapted from the WG-BMSS Inventory of Existing or Planned TDAs. Planned TDAs are denoted by italics and applications where there is a national requirement but no available TDA are indicated with a ✓.

| TDA Application | Lead Nation |
|---|---|
| Infrared | US |
| Visible/Near IR | GE |
| EM (RF/μ-wave) Propagation | UK |
| Acoustic Propagation | US |
| NBC/Smoke | GE |
| Airframe Icing | CA |
| Wind Chill/Heat Stress | NL |

Table 2. Lead nations for reviewing different TDA applications.

Where presentational aspects are concerned, it is likely that different nations, or perhaps even different services within a nation, will wish to have customised output, so it is probably not appropriate to standardise on this. Another factor to be considered is that different nations have already invested in developing certain TDAs and will not wish to withdraw these from use and replace them with another, particularly if the alternative looks very different. However, it may be that different TDA sub-models could be used if this is considered to be of benefit. Thus, one of the aims of this work is to standardise on the actual models/sub-models being used.

## *3.* REVIEW OF TDA APPLICATIONS

A summary of the current status and progress made in some of the different application areas is given below, space precludes a description of all the subject areas. The details given here are largely based upon the results of a recent Technical Review held at the German Military Geophysical Office (GMGO) during May 1996 and described in RECORD MCMG/WG-BMSS-2[1] with an update following the recent November 1996 WG-BMSS-3 meeting. Those applications discussed are introduced in alphabetical order.

### 3.1 Airframe Icing

In certain conditions ice will form on, and adhere to, parts of the airframe and engine. Whilst various preventative measures, plus the performance and capability of modern aircraft, have reduced the frequency of this hazard, it is still an important factor to be considered in aircraft operations. Potentially dangerous effects are: (i) ice may alter the wing profile, reducing the available lift, (ii) engine intakes may become blocked, causing loss of power, (iii) the weight of ice may overload the aircraft, and (iv) forward facing windows may become opaque. For helicopters there are additional risks, (v) uneven ice accretion on the rotor blades, causing severe vibration and (vi) cyclic pitch controls may become jammed, causing loss of control. Clearly, icing forecasts are important to aircraft, particularly helicopter, operations and these predictions are usually expressed in terms of the intensity of expected ice accretion: i.e. trace, light, moderate or severe, and there are a variety of icing forecasting techniques currently used in the US and Europe.

A recent study by the US Air Force (Cornell et al[2]), suggested that the Air Weather Service (AWS) decision-tree method (which is based on empirical aircraft icing forecasting rules) performed best out of three (1 US Air Force, 2 US Navy) techniques investigated and concluded that more rigorous techniques, based on cloud liquid water content (LWC) and dropsize distribution were needed to improve the quality of icing forecasts. Within the WG-BMSS forum there are a number of other methods that have been discussed. These vary in sophistication from a modified version of the AWS decision-tree approach as used by the NL, and a similar technique used by GE, through to the computer-based Ice For Windows (IFW) TDA developed by CA. The IFW TDA is based on a program to forecast icing on fixed and rotor winged aircraft developed for the US Army Atmospheric Sciences Laboratory in the late 80's. Given information cm cloud layers and an atmospheric vertical profile, the model forecasts the severity of the icing conditions.

From an initial comparison of the NL and GE decision-tree methods and the IFW TDA against some 40 reported cases of icing in CA, Yip[1] found that the NL method appeared to give the most reliable results, with 34 correct predictions of icing category with the GE method being correct for 27 of the cases. The lower performance of the GE method was due in part to the absence of a "100 nautical miles ahead of a warm front" category which is included in the NL method. Rather surprisingly the IFW TDA, despite being more sophisticated, proved to be less reliable with a tendency to under-forecast the severity of the icing category. In the interim CA have developed an automated (windows-based) modified Aircraft Icing Flow Chart (AIFC) code that combines the strengths of the NL and GE methods, and this has been made available to NATO nations. However, in the longer term, it is considered that the (updated) Smith-Feddes cloud physics model, which forms the basis of the IFW TDA, needs to be properly examined as some of the assumptions made may not be valid and could partly explain the poorer performance of the IFW TDA. Given the availability of an improved cloud physics model, it is considered that the more rigorous approach ought to produce more reliable results.

As the currently available validation data is rather limited, CA plans to collect more icing reports over the coming winter to further assess the different methods. Given this, and an improved cloud physics model for the IFW TDA, it is expected that it should be possible to make a more definitive recommendation on which method should be adopted for the NATO TDA library during 1997. With a reliable description of the cloud environment (i.e. LWC, temperature, drop size distribution) it is then possible, using an ice accretion model, to predict the extent of ice accretion on aircraft surfaces. Such a model has been developed by GMGO, Brueggemann[1], and it is intended that this model will eventually be linked to a cloud physics prediction model to provide a complete system for determining the extent of ice accretion on specific aircraft and helicopters.

### *3.2* Atmospheric Acoustic Propagation

The propagation of sound near the ground is a complex problem involving a number of different mechanisms. In addition to spherical spreading and atmospheric absorption, (which are straightforward) the effects of refraction (by wind and temperature gradients), scattering (by atmospheric turbulence), and reflection and diffraction from the surface are important. There are two main applications for atmospheric acoustic propagation models, (i) predicting the performance of acoustic sensor systems for detecting guns, helicopters and ground vehicles, and (ii) for noise assessment and mitigation at military and test ranges. Over the years considerable effort has been made with regard to the latter problem and several nations have made noise predictions operationally for many years. Whilst many simple acoustic propagation models exist, these often fail to take proper account of the meteorological conditions which can have a significant effect on long-range sound propagation, giving rise to areas of sound enhancement, shadows and focusing.

An example of an early prediction method, which includes meteorology, is the semi-empirical Larkhill model (Turton et al[3]). This model has been used operationally in the UK (LARKW) since the early 80's and is also used in the NL and GE (SNDCAL), where it has been assessed and shown to give good results (Kießling and aufm Kampe[1]). However, recently both the UK (West et al') and US (Olsen and Noble') have introduced more sophisticated hybrid ray/parametric models into use, these being the APP (Acoustic Prediction Package) and the NAPS (Noise Assessment and Prediction System) respectively. A validation of the APP[4] has shown that it is an improvement on the Larkhill model used previously, whilst an evaluation of the NAPS has been reported by Okrasinski and Dennis[6]. These models are candidates for adoption as a NATO library model for predicting blast noise from ranges. This is a problem which is affecting more countries throughout Europe as noise pollution increasingly becomes a politically sensitive issue.

Whilst the latest models (APP, NAPS) offer improved prediction accuracy compared to the older methods, they are still unable to account for the effects of terrain (e.g. water surfaces), topography (hills and valleys) and turbulence (which scatters sound energy into shadow zones). Parabolic Equation (PE) based techniques are now being applied and these are capable of representing these effects. In the longer term it is expected that PE based models will replace the ray based models used in the APP and NAPS. These effects are particularly significant when predicting the performance of acoustic sensor systems, e.g. sound scattering by turbulence can aid sensor systems in locating targets which are downwind. Reliable prediction systems for acoustic sensor systems must await the availability of mature, fully validated, PE models which incorporate all of the factors noted above.

### 3.3 EM (lW/p-wave) Propagation

Environmental conditions affect the propagation of RF signals in four different ways: (i) refraction, (ii) attenuation, (iii) ground/terrain effects, and (iv) troposcatter. Refractive effects affect the performance of radar, giving rise to extended ranges in ducting conditions and reduced ranges in sub-refracting conditions and can affect the performance of radars used for target acquisition, range-finding, tracking and communications.

Current operational propagation assessment TDAs such as the US Navy REPS (Integrated Refractive Effects Prediction System) are based on ray tracing. However, in recent years there has been considerable effort in developing PE methods for making field strength calculations.

One of the benefits of the PE approach is that it can give more quantitative information on the propagation, in particular it is able to predict 'skip' zones.

In recent years, the military emphasis has shifted very strongly from operations over the open ocean to operating in coastal waters (the littoral environment) where the atmospheric environment is much more complex and variable, and it is essential that range-dependent conditions are available for propagation modelling since conditions vary significantly along the path. Range-dependent PE models, that can also include terrain, have been developed which enables both land/sea and coastal applications. However, PE models are more computationally demanding and much slower to run. Due to the computation required to run PE models, faster hybrid models have been developed for operational use. These include the US Navy RPO (Radio Physical Optics) model and the TERPEM (TERrain Parabolic Equation Model) developed for the RN EEMS (Environmental Electromagnetic Modelling System) as noted at the July 1995 ISWG.3 meeting'. More recently, the US Navy have combined the RPO model and their TPEM (Terrain Parabolic Equation Model) to form the RPOT (Radio Propagation Over Terrain) propagation assessment system.

As noted above, the emphasis is now on predicting radar performance in the littoral environment, which demands the use of range-dependent schemes able to account for the effects of topography/terrain, and appropriate models (RPOT, TERPEM) have been developed for operational use in the US and the UK. Whether or not, these models can be made available to WG-BMSS for inclusion in a NATO TDA-library has yet to be established.

### *3.4* Infrared

Atmospheric propagation of infrared radiation is of importance for many military EO systems. Infrared systems are not all-weather systems and are affected by weather and other environmental effects. Consequently, a number of TDAs for infrared systems have been developed. The simplest of these is the UK infrared "visibility" calculator (IRVIS), although more sophisticated TDAs have been developed in the US and GE. In the US there are three different TDAs for each of the three services: the Air Force EOTDA 3.1, the Navy EOMDA and the Army TARGAC (although all of these are derived from the EOTDA). The TARGAC model has been developed to account for the effects of smoke and dust, which can be important in army operations, whilst the EOMDA has been modified to better represent the maritime environment for US Navy use. However, only an earlier version of the US Air Force EOTDA (v2) has previously been made available to NATO nations and there is general consensus that this version is insufficiently reliable. However, the version EOTDA 3.1 is reported to be much improved. Indeed, the US Air Force consider that the basic models in EOTDA 3.1 have reached a plateau and are now applying these models in the ACT/EOS (Air Combat Targeting/EO Simulation) programme for generating scene visualization capabilities (Alleca[8]).

Similar capabilities have also been developed by GMGO in their NAVFLIR TDA, as described by von Ruesten[1]. This TDA is designed to support the use of airborne FLIR used for navigation rather than targeting and provides predictions of temperature contrasts and FLIR "ranges" for a variety of natural backgrounds, as well as some simple visualization products. Results from the

NAVFLIR TDAarecurrently being verified by GMGO and will be reported on through WG-BMSS. The NAVFLIR model has also been linked directly to the GMGO BLM (Boundary Layer Model) prediction model to produce forecast charts of infra-red range for selected background combinations. Such charts show the spatial and temporal variation in the infra-red "visibility" and have potential for use in the advance planning of air sorties.

Considerable work on compiling verification and validation results is likely before WG-BMSS can recommend any of the above models for inclusion in the NATO TDA library. However, at this time only the GE NAVFLIR TDA and the simpler UK IRVIS calculator have been confirmed as being available for consideration. The availability of the latest US models to NATO has still to be established, but it is possible that commercial considerations may preclude some of these being released.

## 3.5 NBC/Smoke

Current NATO NBC doctrine is in accordance with ATP-45 (STANAG 2103). Whilst this is largely based on manual techniques, these are being replaced by computer-based implementations, although the methods used remain relatively simple. Within the civil sector most regulatory models used are based on Gaussian diffusion and these models make a number of assumptions which are not normally met (e.g. on the homogeneity of meteorological conditions). However, they are still used because of their low computational requirements. More sophisticated particle models are available, which overcome the shortcomings of the Gaussian model, but these are much more computationally demanding and so are not suitable for warning purposes. A compromise between these two extremes are the Gaussian puff models, which simulate a release of gases or aerosols by a series of single puffs, which themselves behave in a Gaussian manner, but are independent of each other. In this way inhomogeneous meteorological fields can be handled, whilst the computational requirements remain within acceptable limits.

All Gaussian models require a set of parameters which depend upon the local environment and weather conditions. These cannot be derived theoretically but must be determined from field measurements. As a consequence, parameter sets have been described for different scenarios by various authors and these show considerable differences. Important factors, amongst others, influencing these parameters are the atmospheric stability, the emission height and the exposure time. Therefore a model used for warning purposes should be able to choose a parameter set which is most appropriate to the situation at hand. An examination of these "sigma parameters" has been made by aufm Kampe and Weber[9], who concluded that there is no reason to change the . . ATP-45 parameters since they show excellent agreement with available experimental data. However at distances greater than 10 km there is substantial disagreement with the data, and there is a need for longer range diffusion experiments, especially under very stable conditions.

More sophisticated dispersion models are being developed by GE (HEARTS - Hazard Estimation after Accidental Release of Toxic Substances, aufm Karp e and Weber[1]), the US (ABCSIM - Atmospheric, Biological and Chemical SIMulator, Brown[1]) and various models are also being assessed in the UK (e.g. ADMS - Atmospheric Dispersion Modelling System, Carruthers et al'"). For military applications, such dispersion models need to be able to handle episodic, localised, small sources where the release is often near the surface. Therefore it is necessary to represent the effects of turbulence and terrain (e.g. the influence of hills, woodland and urban areas). It is also important to be able to consider the effects of short term and fluctuating exposures to toxic materials. Transport over complex terrain can be split into two main contributing factors: wind flow and dispersion effects. At present the simpler flow over terrain models, which can be integrated into dispersion TDAs, cannot account for all situations (e.g. they often break down in severe terrain or very stable conditions) and these limitations need to be addressed.

In the longer term the adoption of more sophisticated dispersion models for NBC purposes within NATO must be co-ordinated with the relevant NATO groups (NAAG Land Group 7 and the MAS NBC WP) with the improved techniques being documented within ATP-45. Whilst the adoption of improved models will bring a benefit in terms of the more accurate prediction of BC hazard areas, the penalty of adopting more sophisticated dispersion models is that they require more reliable and detailed meteorological data than the current ATP-45 "broad-brush" methods. Nevertheless, this is an area where current NATO practices could be brought more up to date, and WG-BMS S are well placed to make appropriate recommendations on models to be used to the other NATO groups mentioned above.

3.6 Visible/Near IR

Within the NATO community a number of different TDAs for supporting the use of Night Vision Goggles (NVG) have been developed. These include the ANVIS (CA), ILLUMW (UK), NITELITE (US) and NVG (US) astronomical models, together with the BIVPROG (GE) and EOTDA TV module (US) which also predict NVG "visual range". Also, in the US, the Night Vision Goggles Operations Weather Software (NOWS) is being developed (Alleca[8]) and this will provide, in addition to predictions of illumination levels, target detection ranges and cloud free line of sight probabilities. Future versions of NOWS are expected to include NVG scene visualization.

As many of these TDAs are relatively mature some verifications have been reported. These include an evaluation of the accuracy of some of the US astronomical models (Keith[11]) and comparison of the predicted illumination levels from some of the available models against measurements made in Canada and Germany (Gross[1]) which have highlighted some consistent differences between the models. It was found that the US NVG model tends to predict the lowest illumination levels whilst the UK ILLUMW tended to give the highest values. Cultural lighting effects were present in the data and this was believed to be a cause of some of the . . discrepancy between the model predictions and the measurements. As yet, the models have only been assessed against a limited dataset; however, there is a much larger database of illumination measurements available at GMGO and it is planned to use this for a more complete verification

One of the characteristics of the various models is that they predict the photometric (0.4-0.7 pm) illumination whilst Gen III NVG are sensitive into the near infrared (0.6-0.9 µm) and there is the question of whether this is a significant limitation of the models. However, theoretical considerations and comparisons of photometric/radiometric measurements suggest that there is a linear relationship between the photometric illumination and the near infrared irradiance so this can be accounted for relatively simply. The BIVPROG TDA also provides predictions of NVG visual range (as a function of illumination and the meteorological visibility) which are based on a multi-linear regression of data from pilot debriefings, whilst the US TVTDA computes detection ranges based on the sensor characteristics. Further data are required to verify these range predictions.

Given the availability of a number of different TDAs for NVG systems and verification/validation results, it is expected that WG-BMS S should be able to make recommendations in 1997 on which TDA, or TDA sub-models, for supporting the use of NVG, should be adopted for the NATO TDA library.

### 3.7 Other Applications

Other applications for which TDAs are being developed include: models for predicting runway icing conditions (as developed by GE and the UK), the US Navy Topside Ship Icing model, new contrail prediction techniques, models for trafficability, parachute operations (in particular a new technique developed by FR to support long range parachute insertions) and HF propagation. Another area which is of interest to many nations is in personnel factors (heat stress/wind chill etc.). This is an area which is being led by the Royal NL Air Force who are commissioning an "expert system" for predicting personnel factors which considers both meteorological and physiological effects. In addition to the previously mentioned TDAs for individual applications, there is also the possibility of providing advice on how weather impacts an entire mission, by looking at the weather effects on all the systems likely to be used. This is the rationale behind the US Army Research Laboratory Integrated Weather Effects Decision Aid (IWEDA), Sauter[12], which is a knowledge-based expert system designed to provide weather effects information at all organisational levels, with the ability to examine weather impacts on specific systems.

## 4. DISCUSSION AND FUTURE DEVELOPMENTS

Current meteorological support, as provided by the various NATO Weather Analysis Centres (WACs) and Military Forecast Centres (MFCs) is based on Numerical Weather Prediction (NWP) products for the theatre of operations. This in turn, demands the availability of high resolution relocatable (i.e. can be configured for different regions) models for the areas of operations. Such models are available to GE, the UK and the US. In addition to these there are many other high resolution models, which are centred over national territories, run at various WACS. However, there is a real need to improve on the quality of the predictions of moisture parameters (e.g. humidity, cloud, precipitation) from these models, since these are critical inputs to many TDAs, and at present generally require manual forecaster input.

In general, mission-specific and tactical forecasts (using TDAs) require more detailed meteorological data on the battle-area scale than can be produced at WACS and this is being addressed by the development of very high resolution battle-area scale models. The need for these battle-area predictions is in the theatre of operations, and it is considered that the ability of such models to produce more accurate meteorological forecasts will largely depend upon their ability to assimilate more up to date in-theatre data. This suggests that these models would probably have to be run in-theatre since they would need to be able to assimilate, in short time, various sources of meteorological data from the operational area. Such models are currently being developed, these include the US Army Battlescale Forecast Model (BFM), Lee et al[13], the US Navy Coupled Ocean Atmosphere Mesoscale Prediction System (COAMPS), Hodur[14] and for the British Army the Computerised Meteorological System (CMETS), Turton[15].

The availability of such models, together with the development of new systems to collect meteorological data from the battle-area (surface sensors, military radiosonde systems, remote profilers, sensors on air vehicles, satellites etc.), should lead to improved predictions of local effects such as those caused by topography/terrain/coasts. This in turn should lead to improved tactical forecasts made using TDAs. At present many of the TDAs that have been developed are stand-alone and run on a variety of disparate platforms. In the longer term it is envisaged that such battle-area scale models and the various meteorological TDAs will be integrated together such that TDAs for various applications would all be run using data from a single, consistent, very high resolution, 4 dimensional meteorological database.

It is expected that the NATO library of TDAs would be made available for nations to use on national Command, Control and Information Systems (CCIS) as well as on NATO CCIS, e.g. the SACLANT Allied Environmental Support System (AESS), and the planned SACEUR Automated CCIS (ACE ACCIS). Currently, AESS includes TDAs for electromagnetic/electro-optic systems and there are requirements for TDAs for NBC defence, mine warfare and amphibious warfare. Similarly, there are national plans to include the various TDAs within integrated systems such as the GE Geophysical Display System (GEDIS), the NL Meteorological Information System (METIS), the UK CMETS and the US Integrated Meteorological System (IMETS).

The provision of 4 dimensional gridded meteorological data fields into NATO CCIS, and within the context of the “digitised battlefield’, is likely to be an issue that will need to be addressed by WG-OPC, as it will be necessary to ensure that the NATO CCIS are capable of handling the appropriate meteorological message formats. In the longer term there may be a need to transmit meteorological data between different national (and NATO) systems and this is an area currently being investigated by WG-OPC.

To conclude, it is envisioned that the NATO library of TDAs will help to ensure the consistency of TDAs on various national and NATO systems, thus improving the consistency of tactical meteorological advice and supporting interoperability within NATO.

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